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Mysterious Neutrinos

RESEARCHERS ARE ONE STEP CLOSER TO DETERMINING HOW HEAVY THE UNIVERSE'S LIGHTEST MATTER PARTICLE MIGHT BE

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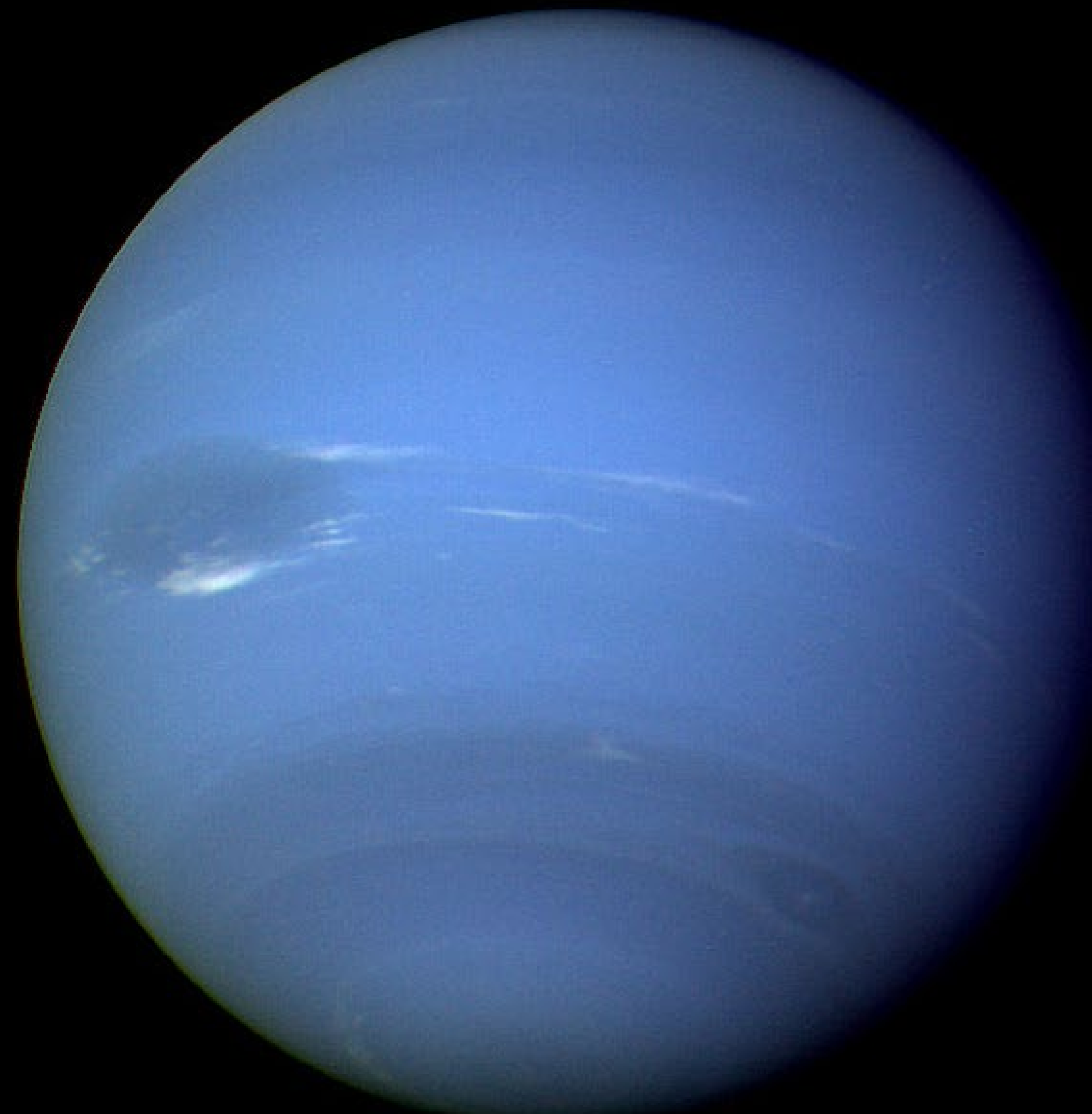
FUTURE MISSIONS TO THE OUTER PLANETS

WITH COVERAGE FROM nature

Neptune, as seen by NASA's Voyager 2 probe during its 1989 flyby of the ice-giant planet.



NASA AND JPL

The Solar System's Loneliest Planets, Revisited

Thirty years after a probe visited Neptune, many scientists say now is the time to finally return to that world and Uranus

By Shannon Hall

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ON AUGUST 25, 1989, IN PASADENA, CALIF., NASA'S JET PROPULSION LABORATORY WAS bustling with activity. Scientists, reporters and even a bona fide rock star, Chuck Berry, had flocked to the facility's mission control to commemorate the moment the Voyager 2 spacecraft flew shy of 5,000 kilometers above Neptune's north pole the previous evening—marking its closest pass to the ice giant. "The level of excitement is the highest I've ever seen here," Carl Sagan later said on a CNN television segment.

That excitement had been building for more than a year as the spacecraft slowly approached what is now considered the sun's outermost known planet. Day by day, the exhilaration grew as Voyager 2 beamed back pictures—incrementally transforming a blurry cluster of pixels into a looming, beautiful blue orb. "It got to the point where, every day, when a new set of images came down, there would be new discoveries on the planet," says Heidi Hammel, who was a member of Voyager 2's imaging science team. Hammel's logbooks from that time are filled with her sketches of those images—along with "Wow!" "Gosh!" and other exclamations scrawled in the margins.

Each image revealed an unexpectedly dynamic world—one with methane-rich clouds, violent storms larger than Earth and planetary winds that, at more than 2,000 kilometers per hour, are the fastest in the solar system. Even Neptune's large, frozen moon Triton churned with geysers and other surprising signs of geologic activity. "Every day was an adventure," Hammel recalls. "It was just a remarkable time of discovery."

But then Voyager 2 continued onward—leaving Neptune in solitude, as it had left behind our solar system's other ice giant, Uranus, after flying by it in 1986. "Our detailed knowledge of the ice giant systems is pretty much frozen at that time," says Anne Verbiscer, a planetary scientist at the University of Virginia. After 30 years, no space agency has returned to Neptune or Uranus, and the questions that Voyager 2 raised about each world remain mostly unanswered. "We think we're so busy in space, but we're busy at Mars," says Candice Hansen, a scientist who was on the Voyager imaging team during the flybys. "Once you get beyond that, there just aren't that many missions that have flown out that far. There's so much still to learn."

Luckily, the tides might soon be turning. Thanks to a renewed interest from the planetary science community and fortunate timing, a second mission might race toward those frigid and mysterious worlds relatively soon.

That is not to say that scientists have failed to study Uranus and Neptune here on Earth. On the contrary, astronomers often swivel the mirrors of giant telescopes on the ground and in orbit toward the solar system's outskirts to observe those faraway giants. But at such great distances, Uranus and Neptune each appear as minuscule blobs. As such, it has taken a number of tricks to better image them. Scientists have shot lasers into the night sky to sharpen their pictures; they have studied Triton's atmosphere as that moon passed in front of a distant star; and they have run experiments on Earth to better comprehend the odd ice that exists within these planets. But these efforts are not enough. "You just can't do the kind of science from Earth that you can do if you're in the environment itself," says Mark Showalter, a planetary astronomer at the SETI Institute.

The issue is that missions to the outer solar system, while doable, are far from easy—in part because they take at least a decade. "It is a lot easier when you can develop a mission and launch it within two years," says Hammel, now executive vice president of the Association of Universities for Research in Astronomy in Washington, D.C. "It's within a presidential funding cycle." Moreover, far from a star, a spacecraft cannot rely on solar power and instead uses nuclear fuel—such as plutonium 238, which offers a steady heat supply that makes it an ideal power source for dark voyages. But NASA's acquisition of that radioisotope has long been sporadic. That much was made painfully clear to Hansen, now a senior scientist at the Planetary Science Institute, in 2003. She was on the verge of proposing a mission to the ice giants when NASA announced it had run out of available plutonium—providing the death blow to her proposal. "It just wasn't in the cards," Hansen says. "But it was hard for me to let go of that, I have to admit." Luckily the hiatus did not last long. In 2011 Congress supplied the funds that allowed the Department of Energy to resume plutonium production for NASA—and with it, the ability to once again reach for the solar system's horizons.

NASA's nuclear rejuvenation could not arrive at a better time. To begin, there is no question that such a mission would revolutionize our understanding of the outer solar system, simply by virtue of voyaging there after three decades of further technological development and scientific discovery. What is more, in the late 2020s, the planets will be positioned so that a Neptune-bound spacecraft can get a gravity assist from Jupiter, picking up tremendous speed from swinging by the giant planet and shaving years off the travel time. Finally, a mission to Uranus needs to reach the world before 2050 in order to see its northern hemisphere for the first time. (When Voyager 2 flew past Uranus, only the planet's southern hemisphere was illuminated.) "I'm hopeful because that puts a little bit more pressure on NASA," says Mark Hofstadter, a planetary scientist at JPL. "But in the back of my mind, there's a fear that if we miss it, I'm going to miss the boat." Hofstadter is 56 years old and would therefore be in his mid-70s when—if—a mission reaches the ice giants in the late 2030s. To him and many other planetary scientists on the verge of retirement, an accepted mission would be bittersweet. "I like to joke that they'll have to reserve a rocking chair and a drooling rag for me by the time we get there," Hansen says.

"The challenge, of course, is that there are many fabulous places to go in our solar system."
—Heidi Hammel

Recent findings from the Kepler space telescope add further impetus for visiting the solar system's ice giants. Based on Kepler's survey of other planetary systems in the Milky Way, scientists are now all but certain that ice giants—a distinct, unique type of world as compared with rocky planets and gas giants—are the most common planets in the galaxy. Our grasp of how worlds are born, evolve and die will remain woefully incomplete without intimately understanding these most abundant denizens of the Milky Way. Yet the ice giants defy many of our most robust models of planetary formation, which suggest such worlds should have grown into full-fledged gas giants akin to Jupiter—only they did not, and scientists are not sure why. Moreover, researchers think that water in the form of ice makes up most of a typical ice giant's interior (hence the name), but certainty on this key detail remains elusive. "We know so little about Uranus and Neptune that to really understand the exoplanets and place them into context, we really need to go back and finish the job for the ice giants," says Mark Marley, a planetary scientist at NASA's Ames Research Center, who studies exoplanets.

Because of that fact, there is a groundswell of support from the exoplanet community, Marley says. Even the last Planetary Science Decadal Survey (a report that determines NASA's exploration priorities for the coming decade) placed a mission to the ice giants third after one that would return samples from Mars and one to Jupiter's moon Europa. Given that those two higher-ranked missions are now well underway, a voyage to the ice giants just might float to the top of NASA's next bucket list.

Already a team of scientists has moved to inform the next Decadal Survey, scheduled for the early 2020s, by publishing a study calling for two separate craft to the outer solar system. One would fly past Uranus, sweeping within its complex magnetic field and potentially dropping a probe into the planet's atmosphere, before leaving to explore smaller, frozen bodies even farther away from the sun. And the other would orbit Neptune, studying both the planet and the mysterious, geyser-spewing Triton.

"The challenge, of course, is that there are many fabulous places to go in our solar system," says Hammel, who admits she is biased. "But I don't want to go back to Mars again. I don't want to go back to Venus again. I don't want to go to another comet. I love them, and they're great science. But where are the mysteries? Where are the unknowns? Where are the giant question marks that we can't address without a spacecraft? To me, that's Uranus and Neptune."